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BRUCE DODSON REYNOLDS

THE VIRGINIA
JOURNAL OF SCIENCE

Vol. 8, New Series July, 1957 No. 3

Bruce Dodson Reynolds 1894-1957

Bruce Dodson Reynolds, fifth of the eleven children of Keene Johnson and Mary Susan Brumfield Reynolds, was born at Renan, Virginia, June 28, 1894. He attended local public schools and Fork Union Military Academy where he played varsity football. After graduating in 1914 he entered the University of Virginia but military duty as a second lieutenant in the Signal Corps and later as a first lieutenant in the Aircraft Production Division of the Army interrupted his college career. However, he returned to the University of Virginia and received his B. S. degree in 1920. He was a Miller Scholar for two years and an Instructor in Biology during his last year. In 1920-21 he was a graduate student and Instructor in Biology at Iowa University. During the next two years he was a Research Fellow in the School of Hygiene and Public Health of the Johns Hopkins University and received the D.Sc. degree in 1923. He spent the next session as Assistant Professor of Biology at the University of Arkansas, and returned to the University of Virginia as Assistant Professor of Biology in 1924. In 1927 he became Associate Professor, in 1938 Professor, and in March, 1957, Chairman of the Department. This post he had held only a little over a month at the time of his sudden death in April.

Dr. Reynolds was a Fellow of the AAAS and a member of the Society of Protozoologists, the American Society of Parasitologists, the American Society of Zoologists, the AIBS, the Virginia Academy of Science and the Association of Southeastern Biologists, serving as President of this last organization in 1953. In the Virginia Academy of Science he had been particularly active in the Junior Academy work.

While Dr. Reynolds had done some work on Hydra and mosquitoes, most of his publications were in the fields of protozoology and parasitology. His most outstanding research was probably that on amoebae and flagellates. He was particularly proud of the large number of graduate students who had completed their training under his supervision and, despite the pressure of administrative duties in recent years, he maintained his interest in his students. As a result they had a strong sense of loyalty to him. Recently he had become intensely interested in early American History. His presidential address before the Association of Southeastern Biologists was on this topic, and because of his studies on Indians he was asked to write an article on the Virginia Indians for

a special issue of the Virginia Journal of Science published this year as a part of the commemoration of the 350th anniversary of the founding of Jamestown. He was also editor of the volume published as a tribute to Dr. Kepner at the time of his retirement in 1946.

The Blandy Experimental Farm and the Mountain Lake Biological Station were very close to Dr. Reynolds' heart and his practical wisdom, untiring energy and faith that the job could be done played an important role in bringing them into existence. Almost every sizable college and university in the country has at one time or another been given a farm comparable to the Blandy Farm, but it stands virtually alone in having developed into a real educational and research unit of the institution involved. Dr. Reynolds as Chairman of the Investigating Committee was instrumental in pointing out the possibilities of the Blandy Farm and in securing Dr. Orland E. White as its first Director.

In the late 1920's there was a good deal of discussion at the University of Virginia as to the relative merits of a marine biological station on the Eastern Shore of Virginia or an inland station at Mountain Lake. Dr. Reynolds was among those who advocated the mountain site and the present standing of the Mountain Lake Biological Station has abundantly vindicated his judgment. He was the first Director of the Station which was established in 1930 in cottages rented from the Mountain Lake Hotel. It was always the institution from which he derived the greatest pleasure and when it was moved to its present location in 1934 his keen interest in it continued even though he was no longer Director. He came to Mountain Lake whenever possible and devoted a great deal of time and energy to the work there, especially to the improvement of the grounds and buildings. In 1946 he again became Director and continued in this capacity until his retirement after the 1956 session. During his second administration the acreage owned by the Station was approximately doubled and funds were secured from the National Science Foundation for the renovation of the physical plant as well as for the support of study and research.

While regular in his attendance at local, regional and national scientific meetings, it was through his work at Mountain Lake that Dr. Reynolds was best known. The many alumni of the Station will remember how he took part in every phase of life at Mountain Lake: scientific, social, athletic or just plain physical labor. He loved it all from pitching horseshoes to presiding over scientific meetings; from laying water pipes and digging rocks to booming forth with his deep bass voice at the Sunday night sings. His sudden and untimely death came as a shock to all who knew him and biology in the Southeast has suffered a great loss in his passing. He is survived by his wife, Katherine Grayson Reynolds; three children: Bruce D., Jr., Katherine Grayson (Mrs. Carl Stark), May Hollingsworth (Mrs. James P. Elkins); a number of grandchildren; three sisters and two brothers.

E. Ruffin Jones, Jr., *University of Florida*

The Agar Diffusion Technique As Applied To The Study Of Serological Relationships Among Crayfishes[1]

ROSE MARY JOHNSON

University of Virginia

There are reasons for doubting that the present taxonomic treatment accorded the crayfishes of the Genus *Cambarus* (comprising some fifty species and subspecies) expresses the true affinities of this group of organisms. This treatment is based upon limited data from the fields of morphology, ecology, and geographic distribution.

Inasmuch as serological data concerning the interrelationships of organisms have, in general, supported those data obtained from such fields as morphology and embryology, it seems reasonable to assume that this approach might aid in the classification of the members of the Genus *Cambarus*. The present study, therefore, was initiated in anticipation of a better understanding of the interrelationships of the members of this group.

Among the crayfishes there appears to be but one kind of antigenic serum protein, the hemocyanins (Leone, 1949). Therefore, serological variation among crayfishes is due to differences in their hemocyanins. In no case is hemocyanin known to occur in blood corpuscles or within tissue cells.

Until the investigations of Oudin (1952) and Ouchterlony (1949, 1953), it was impossible to demonstrate the number of antigens in an antigenic mixture. Oudin, by adding antigens to a test tube of semi-solid agar containing antiserum, was able to demonstrate the presence of several components in antigenic complexes. Ouchterlony modified the technique, using agar Petri plates. The antigens and antisera for the plate method of Ouchterlony are placed in wells molded in the agar in such a way as to form an isosceles triangle. It is possible to determine which antigenic components are "identical" by utilizing three wells; one containing an antiserum and each of the others containing the antigens to be tested. Antigens and antibodies diffuse from their respective wells and form precipitate lines when they meet. If the two antigenic mixtures are "identical," the lines will meet and fuse. Conversely, if the antigens are

[1] This work is a portion of a thesis presented to the Graduate Faculty of the University of Virginia in partial fulfillment for the Master of Arts Degree.

different but have some components in common, all of the lines will not fuse but will cross one another (reaction of "partial identity" or "non-identity" depending on the degree of heterogeneity).

Elek (1949) further modified Ouchterlony's technique employing strips of filter paper instead of wells in the agar. Strips of filter paper soaked with antigen are placed at right angles to an embedded filter strip soaked with antiserum. "Serological equivalence" (reaction of "identity" of Ouchterlony) is demonstrated by "looping" (fusion) of the precipitate lines between the antigen strips.

MATERIALS AND METHODS

The crayfishes[2] selected for the major portion of this work are at present assigned to three groups of the Genus *Cambarus*. The Bartonii Group is represented in this study by five subspecies: *Cambarus bartonii bartonii* (Fabricius), *C. bartonii sciotensis* Rhoades, *C. bartonii robustus* Girard, *C. bartonii striatus* Hay, and *C. bartonii* subsp. The Montanus Group is represented by a single subspecies, *C. montanus acuminatus* Faxon, and it is suspected that this form is identical to *C. bartonii robustus*. The Longulus Group is represented by three crayfishes; *C. longulus longulus* Girard, *C. longulus longirostris* Faxon, and *Cambarus* sp.

Three species of the genus *Orconectes* [*O. juvenilis* (Hagan), *O. nais* (Faxon)[3] and *O. immunis* (Girard)[3]], one of the Genus *Pacifastacus* [*P. trowbridgii* (Dana)[3]], and one species of the Genus *Procambarus* [*P. hayi* (Faxon)] are included.

The crayfish sera used in these experiments were collected by removal of the last three podomeres of the cheliped and the blood issuing forth was allowed to drop into a glass tube. When possible, the crayfish were starved 24 hours before bleeding. After the blood had clotted, the serum was drawn off and frozen. Total proteins were determined by the method of Looney and Walsh (1939) using the Klett-Summerson photoelectric colorimeter.

Antisera were produced in healthy rabbits weighing between five and eight pounds. The injection schedules were patterned after those of Leone (1949, 1952). Since this schedule failed to produce antisera of high enough titer in some cases, a pre-sensitizing injection was given subcutaneously followed in thirty days by four intravenous injections on alternate days (Table 1). All antisera were sterilized through a Seitz filter and stored in a freezer.

[2] Personal communication from Dr. Horton H. Hobbs, Jr., University of Virginia, who also identified the crayfishes utilized in this study, and suggested the problem.

[3] These sera were kindly supplied by Dr. Charles A. Leone, University of Kansas, Lawrence, Kansas.

TABLE 1 (See Text)

SPECIES	INJECTION SCHEDULE
C. m. acuminatus	0.25cc, 0.50cc, 0.50cc, 0.50cc. IV. on alternate days; 0.50 IV two weeks later (booster); blood collected from heart two weeks after booster.
C. b. sciotensis	0.40cc subcut.; after thirty days, 0.50cc, 0.80cc, 1.0cc. 1.0cc IV on alternate days; blood was collected from heart ten days after last injection.
C. b. bartonii	0.25cc, 0.50cc, 0.50cc, 0.50cc IV on alternate days; 0.50cc IV two weeks later (booster); blood collected from heart one week after booster.
C. b. robustus	0.50cc subcut.; after thirty days, 0.30cc, 0.60cc, 0.60cc, 0.80cc IV on alternate days; 1.0cc IV eight days later (booster); blood was collected from heart twelve days after booster.

The procedure used was essentially the same as reported by Elek (1949). A thin layer of 1.5% agar was poured into a Petri dish. After solidification of the agar, a strip of filter paper, 35mm by 15mm, which had been soaked in undiluted antiserum (about eight drops) was placed on the surface of the agar. Strips of filter paper, 25mm by 4mm, soaked in antigen (crayfish serum) were placed on the surface of the agar, parallel to each other, and at right angles to the strip containing antiserum. A series of antigen dilutions was tested and 1400 gamma of protein/cc seemed to give an optimum precipitate line, therefore, the antigens for this series of tests were diluted to contain 1400 gamma of protein/cc. The plates were sealed and incubated for from 48 to 72 hours at 37.5° C.

There are certain limitations to the agar diffusion technique as artifacts may appear in the agar which may be confused with bands of precipitate. These false bands or "striae" appear as a result of sudden temperature change (Munoz, 1954). For this reason, the results were interpreted immediately after suitable incubation and all tests were repeated. Other interesting observations have been made with reference to interpretation of the Ouchterlony plate method by Korngold (1956) and Wilson and Pringle (1956).

RESULTS AND CONCLUSION

Table 2 shows the results of the right-angled double-diffusion technique of Elek. The term "partial loop" has been used to denote some

degree of heterogeneity (termed reaction of "partial identity" by Ouchterlony, 1953), but no attempt has been made to interpret the degree of correspondence since this is a qualitative method.

All of the crayfishes showed serological equivalence between some of the antigenic components. The straight line (termed "spur" by Ouchterlony, 1953) ascending from the filter strips containing homologous antigen (*e.g.*, Fig. 3, the vertical strips labeled *C. b. bartonii*), however, illustrates clearly that some of the antigenic components of *Orconectes juvenilis, Orconectes* sp., and *Pacifastacus trowbridgii* are not serologically equivalent (*cf.*, Fig. 1.)

The formation of multiple precipitate lines in Fig. 2 and Fig. 4 support the assumption that more than one antigenic component may be present in the hemocyanins of the crayfishes.

It may be noted in Table 2 that the five subspecies of the Bartonii Group exhibited complete serological equivalence. Also, the serum pro-

EXPLANATION OF FIGURES

Fig. 1 — Photograph of a typical agar diffusion Petri plate demonstrating serological equivalence as indicated by a "looping" of the precipitate lines. Above the antiserum strip, containing the antiserum prepared against *C. montanus acuminatus,* is a homologous "loop" between the the two antigen strips containing *C. montanus acuminatus* serum. On the opposite side of the antiserum strip is a "loop" demonstrating serological equivalence between *C. montanus acuminatus* and *C. bartonii sciotensis.*

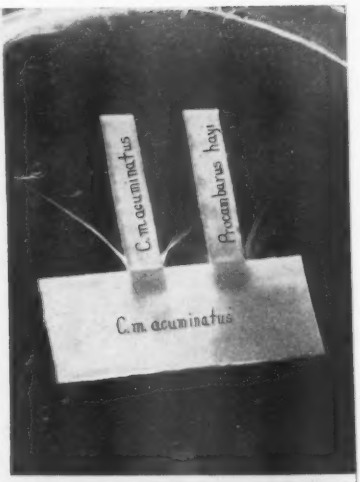
Fig. 2. — Photograph of an agar diffusion plate illustrating an heterologous reaction between the sera of *C. montanus acuminatus* and *Procambarus hayi.* Note the multiple precipitate lines developed by the heterologous antigen of *P. hayi* and the antiserum prepared against *C. montanus acuminatus.*

Fig. 3. — Photograph of an agar diffusion plate demonstrating serological equivalence between the homologous antigen, *C. bartonii bartonii,* and *C. bartonii robustus.* Also, a partial heterogeneity can be seen between the homologous antigen and two members of the Genus *Orconectes* and one member of the Genus *Pacifastacus.*

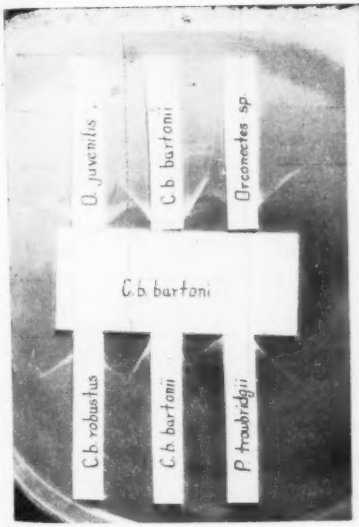
Fig. 4. — Photograph of an agar diffusion plate demonstrating serological equivalence between *C. bartonii robustus* and three other subspecies of the Genus *Cambarus.* Note the double precipitate lines suggesting that there are two flocculating systems involved. Each time antigens were tested with the antiserum prepared against *C. bartonii robustus,* two precipitate lines developed.

C. m. acuminatus
C. m. acuminatus
C. m. acuminatus
C. m. acuminatus
C. b. scotensis

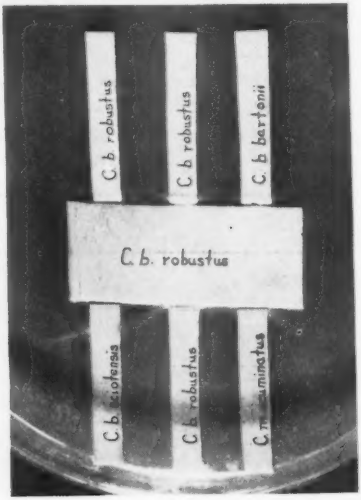
1


C. m. acuminatus
Arcanobacterium hayi
C. m. acuminatus

2


O. juvenilis
C. b. bartonii
Orconectes sp.
C. b. bartonii
C. b. robustus
C. b. bartonii
P. troubridgii

3


C. b. robustus
C. b. robustus
C. b. bartonii
C. b. robustus
C. b. scotensis
C. b. robustus
C. m. acuminatus

4

TABLE 2 (See Text)

ANTIGENS (*Crayfish Serum*)	ANTIBODY (RABBIT ANTI-CRAYFISH SERUM)			
	C. b sciotensis	*C. m. acuminatus*	*C. b. bartonii*	*C. b. robustus*
C. b. sciotensis	L	L	L	L
C. m. acuminatus	L	L	L	L
C. b. bartonii	L	L	L	L
C. b. robustus	L	L	L	L
C. b. striatus	L	L	L	L
***C. b.* subsp.**	L	L	PL	L
C. l. longulus	L	L	PL	L
C. l. longirostris	L	L	PL	L
***C.* species**	L	L	PL	L
O. juvenilis	L	PL	PL	L
O. immunis	L	PL	PL	PL
O. nais	L	PL	PL	PL
P. trowbridgii	PL	PL	PL	PL

L = loop (serological equivalence)
PL = partial loop (some degree of heterogeneity)

teins of *C. montanus acuminatus* gave serologically equivalent reactions with all the antisera with which it was tested. Therefore, it would seem that this crayfish is serologically equivalent to the members of the Bartonii Group.

Some degree of heterogeneity was indicated between the crayfishes of the Bartonii Group and those of the Longulus Group when the antiserum prepared against *C. bartonii bartonii* was employed (Table 2). This antiserum was probably the most specific of the four since it was able to distinguish serological differences between these two closely related groups of crayfishes.

Most of the antisera demonstrated a partial heterogeneity between the Genus *Cambarus* and the Genus *Orconectes* (Table 2, Fig. 3. All of the antisera were able to detect partial heterogeneity between the Genera *Cambarus* and *Pacifasticus* (Table 2, Fig. 3).

Repeated tests with the reagents (antigen and antibody) used in this study confirmed the results presented in Table 2. The angle and width of the precipitate lines often varied upon repetition of the experiments, but, in each case, either the significant "loop" or the partial "loop" was present.

SUMMARY

Antisera were presented against the serum proteins of *Cambarus bartonii bartonii, C. bartonii sciotensis, C. bartonii robustus,* and *C. montanus acuminatus.* Studies employing these four antisera and utilizing the right-angled double-diffusion method of Elek (1949) were conducted on nine subspecies of the Genus *Cambarus,* one species of *Procambarus,* and three subspecies of *Orconectes,* all members of the subfamily Cambarinae, and one species of the Genus *Pacifastacus,* subfamily Astacinae.

The relationships indicated among the crayfishes compared by this method are in accord with the present system of classification except for the apparent close relationship of *C. montanus acuminatus* (Montanus Group) to the members of the Bartonii Group. From the results of these agar diffusions studies, it is impossible to demonstrate to which member of the Bartonii Group *C. montanus acuminatus* is most closely related.

The formation of multiple precipitate lines supports the assumption that more than one antigenic component may be present in the serum of crayfishes and demonstrates the unique value of this technique in separating the components of an antigenic complex.

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Megasporogenesis and Megagametogenesis in Hamamelis Virginiana L.

FRANKLIN F. FLINT, *Department of Biology,*

Randolph-Macon Woman's College.

Shoemaker (1905) contributed to our knowledge of the general floral structure, the development of the anther, the ovule, and the young embryo in *Hamamelis virginiana*. He did not describe the process of megasporogenesis and megagametogenesis.

MATERIALS AND METHODS

The flowers were collected in the vicinity of Lynchburg, Virginia, along the banks of small streams which flow into the James River. The young ovules were fixed in Formalin-Aceto-Alcohol in the proportions of 90 cc. of 70 percent ethyl alcohol to 5 cc. formalin and 5 cc. of glacial acetic acid. Tertiary butyl alcohol, as recommended by Johansen (1940), was found to be most satisfactory for dehydration. The ovules were then embedded in tissuemat, sectioned at 10-30 microns and stained with Harris' Hematoxylin, Safranin O, and Fast Green, FCF.

MEGASPOROGENESIS

The megaspore mother cell is first distinguishable within the young ovule in late November, lying at the chalazal end of a linear row of 4-5 nucellar cells (fig. 1). The megaspore mother cell is oval and contains a large, vesicular nucleus and dense cytoplasm. As the prophase of Meiosis I begins this cell is more than 3 times the linear dimensions of the immediately surrounding nucellar cells. Development ceases and this division is not completed until April. During the first part of April the nucellar cells begin to divide rapidly and by the middle of the month Meiosis I is completed. Cytokinesis takes place resulting in a dyad of cells of approximately the same size, each with dense cytoplasm and a large, deeply staining nucleus containing a prominent nucleolus (fig. 2). Meiosis II and cytokinesis take place immediately and 4 cells, the megaspores, are formed, arranged in a linear row between the micropylar and the chalazal ends of the ovule (fig. 3). A megaspore can easily distinguished from the surrounding nucellar cells by the dense cytoplasm, prominent nucleus, and especially by the single, very large nucleolus. The megaspores vary somewhat in size, with the chalazal one being slightly larger from the beginning and the micropylar one the smallest

(fig. 3). In 69 of the 78 ovules studied, the chalazal megaspores enlarged and became the functional megaspore, the 3 micropylar ones disintegrating. In the remaining 9 ovules one or more of the megaspores enlarged and functioned for a short time as rudimentary megagametophytes (figs. 9, 10, 11). The megaspores which disintegrate do so gradually as the enlarging megagametophyte presses against the surrounding nucellar cells (figs. 4, 5).

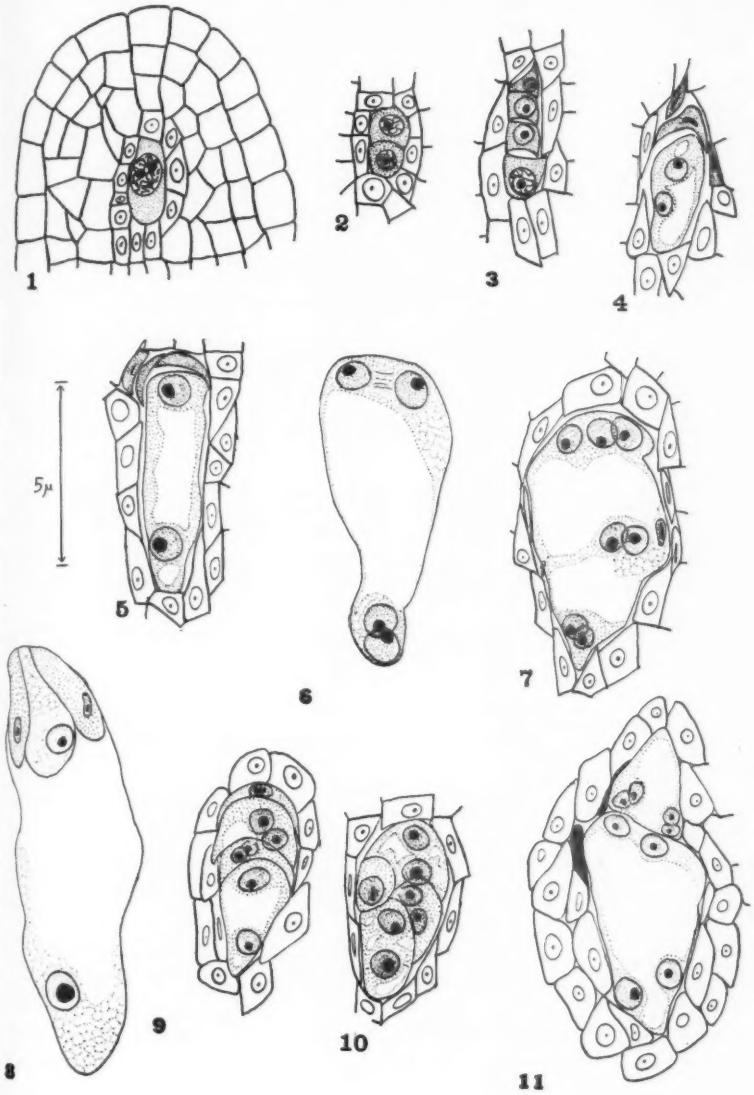
MEGAGAMETOGENESIS

In all cases where the chalazal megaspore is the only functional one, the cell increases greatly in size, the nucleus divides, and gradually a 2-nucleated megagametophyte is formed. As this change takes place a small vacuole forms towards the micropylar end and a larger one develops laterally to the 2 nuclei (fig. 4). As the lateral vacuole increases in size and extends across the center of the enlarging cell one of the nuclei and part of the cytoplasm move towards the micropylar end and the other nucleus and the remainder of the cytoplasm towards the chalazal end of the megagametophyte (fig. 5).

The 2 nuclei now divide and form a 4-nucleated megagametophyte with 2 nuclei at each end, separated by the large central vacuole (fig. 6). The pair of nuclei at either end of the megagametophyte are oriented at right angles to the opposite pair and both pairs are perpendicular to the major axis of the megagametophyte. At this time the developing megagametophyte is surrounded by many crushed nucellar cells and the three micropylar megaspores disappear completely. The 4 nuclei soon divide resulting in an 8-nucleated megagametophyte (fig. 7). One nucleus from each pole migrates toward the center of the megagametophyte along with a portion of the cytoplasm. Occasionally another nucleus from the antipodal pole is carried towards the center of the cell with the migrating cytoplasm but it soon disintegrates leaving only 2 antipodal nuclei (fig. 7).

Recognizable antipodal cells were not formed in the ovules studied and the antipodal nuclei exist for only a short time. This is contrary to Shoemaker's (1905) work, where, in his only illustration of the megagametophyte, he shows 3 definite antipodal cells. The nuclei which have migrated to the center of the megagametophyte are the polar nuclei. They soon fuse to form the secondary nucleus which is very large and has a prominent nucleolus (fig. 8). This nucleus, embedded in a granular cytoplasm, migrates towards the antipodal pole after the disintegration of the antipodal nuclei (fig. 8).

A cell membrane is formed around each micropylar nucleus incorporating a portion of the cytoplasm. This is the egg apparatus and con-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sists of an egg cell and 2 synergid cells (fig. 8). The nuclei of the 2 synergid cells soon show signs of disintegration and the cytoplasm becomes vacuolated while the egg cell enlarges and extends beyond them (fig. 8).

Any one or all four megaspores may occasionally develop rudimentary megagametophytes. Nearly 12 percent of the 78 ovules studied in detail had more than one megaspore functioning, although in no instance did it appear that a mature megagametophyte developed in such

EXPLANATION OF FIGURES

The figures were made with the aid of an Abbe camera lucida. Size is indicated on the plate.

Fig. 1. — Young ovule showing the megaspore mother cell with nucleus in prophase of Meiosis I buried within the nucellar tissue.

Fig. 2. — Dyad cells formed after Meiosis I as the result of cytokinesis.

Fig. 3. — Linear tetrad of megaspores with the chalazal one enlarging.

Fig. 4. — Two-nucleated megagametophyte with a single lateral vacuole and a smaller vacuole at micropylar end. The 3 megaspores are still visible but degenerate.

Fig. 5. — Two-nucleated megagametophyte with large central vacuole and small vacuole at chalazal end.

Fig. 6. — Four-nucleated megagametophyte.

Fig. 7. — Eight-nucleated megagametophyte with 2 polar nuclei at center. One of the antipodal nuclei has moved towards the center and is disintegrating.

Fig. 8. — Mature megagametophyte showing the complete egg apparatus.

Fig. 9. — Four 2-nucleated megagametophytes formed in 1 ovule. The first and third megagametophytes from the micropylar end are partially crushed.

Fig. 10. — Three of the megaspores have formed 2-nucleated megagametophytes. The fourth megaspore has enlarged but a nuclear division has not taken place.

Fig. 11. — Two megagametophytes at the 4-nucleated stage. The degenerating megaspores are crushed but still recognizable.

an ovule. In 3 ovules all megaspores had formed a 2-nucleated megagametophyte (fig. 9) with the megagametophytes developing from the first and third megaspores from the micropylar end partially crushed and the nuclei partly disintegrated; while the 2 megagametophytes developing from the second and fourth megaspores were continuing to develop with the latter one larger (fig. 9).

Four ovules had 3 of the megaspores developing into large 2-nucleated megagametophytes with vacuoles forming in the cytoplasm. The fourth megaspore had enlarged but a nuclear division had not taken place and there were no vacuoles in the cytoplasm (fig 10).

In 2 ovules it was found that 2 of the megaspores had developed into 4-nucleated megagametophytes with the more chalazal one larger and the micropylar one with nuclear degeneration (fig. 11). The other 2 megaspores in both of these ovules were degenerate and it did not appear that they had enlarged.

SUMMARY

With certain modifications *Hamamelis virginiana* follows the pattern of development listed as the Polygonum Type by Maheshwari (1950). The nucleus of the megaspore mother cell remains in prophase of Meiosis I from late November to early April. In April a linear tetrad of megaspores is formed with the most chalazal one functioning normally. In approximately 12 percent of the ovules studied one or more of the other megaspores functioned to form rudimentary megagametophytes. The antipodal nuclei disintegrated quickly without incorporation into true antipodal cells.

ACKNOWLEDGMENT

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The Effect Of Corn And High Protein Price Ratios On Net Returns In Hog Production[1]

ROY G. STOUT, *Virginia Agricultural Experiment Station*

Many factors influence the total cost of producing hogs, but feed costs are quantitatively most important. Feed costs alone usually comprise 75 to 85 per cent of the total costs (Heady and Jensen, 1954). The other cost items accounting for the remaining 15 to 25 per cent are: (1) labor; (2) depreciation on building and equipment, and interest on investment; (3) rent, death losses, and miscellaneous costs. The net returns from hog production depends on the producer's ability to obtain maximum efficiency from these factors.

Corn is often considered the "basic" hog feed. It makes up a larger portion of the ration for hogs than for any other livestock. However, successful hog producers are aware that a hog ration should contain high protein supplement feeds and minerals in addition to corn. By experience and from research findings, they have found that the addition of protein supplement and minerals to the ration will increase daily gain, reduce feed consumption per unit of gain, and decrease feed costs per unit of gain in comparison with an all corn ration. Nutritional research has repeatedly shown that for both economic and physical reasons hog rations should be balanced so as to contain, in addition to corn and other grains, certain quantities of proteins, minerals, and perhaps limited amounts of antibiotics. Also, experimental feeding tests have shown that the conversion ratio of feed to pork increases as the hog increases in weight[2]. Light weight hogs are more efficient in converting feed into pork than heavier hogs. For example, more feed is required per pound of gain for a hog weighing 220 pounds than for one weighing 160 pounds. Thus, the conversion ratio of the 220 pound hog is greater than the conversion ratio for the hog weighing 160 pounds.

Price relationships between corn and high-protein feeds, such as soybean oilmeal and tankage, usually vary both seasonally and annually. These variations in price relationships (price ratios) are due largely to the variations in the available supply of the different feeds from time to time. During World War II the price ratios between feeds were closer than during any other time in the 15-year period from 1935 to 1950. The

[1] A portion of a Master's Thesis, "Factors Affecting Net Returns from Hog Production with Specil Emphasis on Time of Marketing," submitted to the Graduate School, Virginia Polytechnic Institute, February 1952.

[2] Conversion ratio is defined as the number of pounds of feed necessary to produce one pound of gain.

average price per 100 pounds of soybean oilmeal for the five year period, 1943-1947, was 1.23 times larger than the price of corn; during this same period the ratio of the price of 100 pounds of corn to 100 pounds of tankage was 1 to 1.72[2]. During the years 1935-1939 the average price ratio of soybean oilmeal and tankage to corn was 1 to 1.3 and 1 to 1.91 respectively. The nine year average, 1935-1939 and 1947-1950, price of soybean oilmeal and tankage was 1.42 and 2.05 times, respectively, greater than the price of corn.

Feeding results from several experiments have shown that feed ingredients commonly used in hog rations do not substitute for each other in fixed or constant ratios. Rather, results from these tests show that the physical rate of substitution of these feeds for each other are generally at a diminishing marginal rate. In other words, if by adding, say, two pounds of soybean meal to an all corn ration it would replace, say, five pounds of corn in the ration and still produce as many pounds of pork as before, the substitution ratio between soybean meal and corn would be 1:2.5. But, if an additional, say, two pounds of soybean meal were added, it would not be expected to replace five pounds of corn as the first increment did.

The marginal rate of substitution of protein feeds for corn in producing 100 pounds of pork diminishes as more protein feed is added to the ration. The amount of feed required to produce 100 pounds of gain on hogs may be stated mathematically by:

$$C = f(A+B)$$

where C is total feed
A is the pounds of corn
B is the pounds of protein feed
f is some function of A and B

For the discussion in this paper C is a constant 100 pounds of pork.

The rates of substitution of corn for high protein feed are graphically illustrated in figure 1. The small circles represent results of actual feeding trials from which smooth line curve was constructed (Keith and Miller, 1940). This iso-product curve for producing 100 pounds of pork shows the results of feeding different levels of protein feed to pigs with an initial weight of approximately 125 pounds and feeding them to about 200 pounds. In the experimental feeding trials from which these data were obtained, rations of different protein levels varying from 10 to 25 per cent were fed. Higher rates of substitution of protein feed for corn in the fattening ration will occur when the ration is low in protein con-

[2] All price information on feeds in this paper was taken from Virginia Crops and Livestock, State Department of Agriculture, Virginia Cooperative Crop Reporting Service. Volumes 15 and 19.

tent. For instance, if a ration of 375 pounds of corn and 25 pounds of protein feed (a 10 per cent protein ration) is replaced with a ration composed of 279 pounds of corn and 38 pounds of protein (12 per cent protein ration), the output will be 100 pounds of pork in either case. In this exchange, in going from a 10 to a 12 per cent ration, 13 pounds of high protein feed replaced 96 pounds of corn. But, if a 17 per cent protein ration (composed of 176 pounds of corn and 75 pounds of protein feed) is replaced with a 20 per cent protein ration (composed of 145 pounds of corn and 120 pounds of protein feed), 45 pounds of high protein feed would replace only 31 pounds of corn. Thus the marginal rate of substitution of protein feed for corn is only 1 to 0.6889 ($31 \div 45$) in the 20 per cent protein ration, but in a 12 per cent protein ration a much higher substitution rate of 1 to 7.385 ($96 \div 13$) exists. Hence, as the amount of protein feed or corn is increased in the ration its marginal rate of substitution for the other feed diminishes.

Since feed costs are the most important item affecting total production costs, hog producers should, in light of the above mentioned facts, attempt to feed the most economical ration consistent with minimum nutritional requirements for keeping the hog healthy and growing. The most economical ration will depend upon the relationship between marginal (physical) rates of substitution of the various feed ingredients used and the ratio of their prices. If the 12 per cent protein ration mentioned earlier is to be more economical than the 10 per cent protein ration, the cost of the 13 pounds of high protein feed must be less than the value of the 96 pounds of corn.

The producer must continually keep himself informed of the price relationship of the various feeds that make up the hog ration and adjust his feeding rations accordingly. However, he should not vary his feed ration beyond a nutritionally balanced one, since an unbalanced ration usually affects the healthy condition of the hog. As long as a balanced ration is maintained, a producer may react to an increase in the price of one feed, say corn, by replacing it with another, say soybean oilmeal.

The combination of high protein feeds and corn that will be the optimum combination (least feed cost combination) will be at a point where the marginal rates of substitution of corn for high protein content is equal to the ratio of the price of corn to the price of the high protein feed. If the price of corn is one-half of the price of high protein feed, then the cheapest ration that would produce 100 pounds of pork would be composed of the combination of corn and high protein feed at the point where the last pound of high protein feed added would replace two pounds of corn. At this point, the addition of one more pound of high protein would replace something less than two pounds of corn.

The following two examples give a comparison of the economical

Example One:

Protein Content:	12 (Point A)		17 (Point C)		20 (Point B)	
Corn @ $1.50 per cwt.	279 lbs.	$4.18	176 lbs.	$2.64	145 lbs.	$2.17
High @ $2.50 per cwt.	38 lbs.	$0.95	75 lbs.	$1.87	120 lbs.	$3.00
Protein						
Cost per 100 pounds gain		$5.13		$4.51		$5.17

Price Ratio 1.5:2.5

Example Two:

Protein Content:	12 (Point A)		17 (Point C)		20 (Point B)	
Corn @ $1.00 per cwt.	279 lbs.	$2.79	176 lbs.	$1.76	145 lbs.	$1.45
High @ $3.50 per cwt.	38 lbs.	$1.33	75 lbs.	$2.68	128 lbs.	$4.10
Protein						
Cost per 100 pounds of gain		$4.12		$4.44		$5.55

Price Ratio 1.0:3.5

gains made by choosing the proper protein content ration for various price relationships.

In example one where the price ratio of corn to high protein feed is 1.5:2.5, the 17 per cent protein content ration produces 100 pounds of pork at the least cost. Suppose the supply of high protein content feeds is small, causing an increase in the price to $3.50 per hundred, and the cost of corn declines to $1.00 per hundred. This situation is demonstrated in example two. Since the price of corn decreased and the price of high protein supplement increased, the addition of more corn and less high protein should reduce the feed cost. This, we see, is what happened. For this price ratio of 1.0:3.5, the 12 per cent protein produced 100 pounds of pork cheaper than the 17 per cent.

For any given price ratio, there exists a combination of corn and high protein feed that will produce 100 pounds of pork at less feed cost than any other combination. The two examples suggest one method of finding this least cost combination. This might accurately be called the trial and error method. There may be other rations with the price ratio

of 1.5:2.5 that would be cheaper in terms of feed costs than the 17 per cent ration. The only way to find it with the trial and error method would be to compute the costs for several different rations at a given price ratio and select the ration with the least feed cost per 100 pounds gain. Another method that is easier and less time consuming is to compare the slope of the line of the feed price ratio with the curve of the rates of substitution of corn for protein feed. The point on the iso-production curve where the slope is the same as the slope of the price-ratio line gives the least cost combination of corn and protein for the given price ratio of the feeds. This point is where the price-ratio line is tangent to the iso-production curve. In fig. 1, point A represents the 12 per cent protein ration; points B and C represent the 20 and 17 per cent rations respectively, used in the two examples. In example two, the 12 per cent ration is the cheapest of the three. Is this the cheapest one possible in terms of the cost of corn and high protein feeds? To find the least cost combination line E-E' was drawn. This is the ratio of the prices of 1.0:3.5 (100 pounds high protein costs as much as 350 pounds corn).

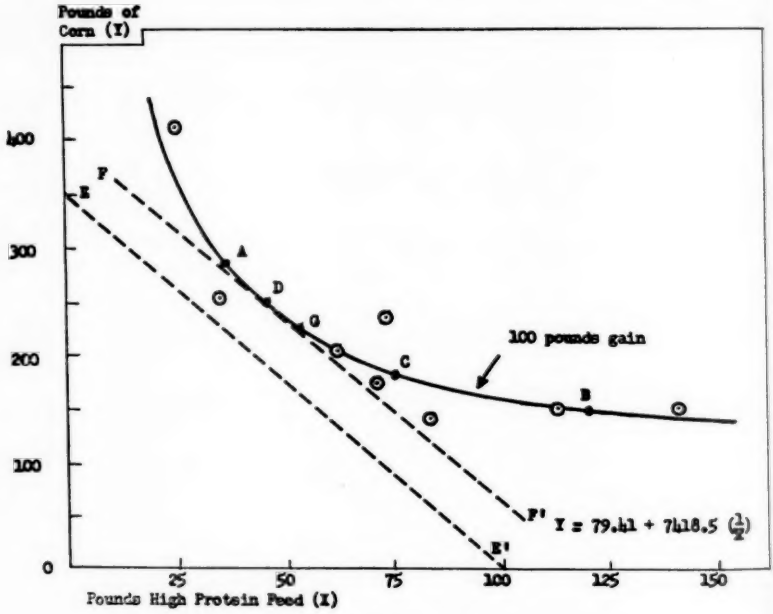

Fig. 1. (See Text).

Then we construct line F-F' parallel to E-E' in such a manner that F-F' touches the iso-product curve (point D). At this point the slopes of the line and the curve are the same. Computing the cost of the feed combination (246 pounds of corn and 44 pounds of high protein), we find that this combination of corn and high protein supplement costs $4.00 per hundred pounds of gain. Thus the 12 per cent protein ration shown in example two was close to the least cost combination, but not the cheapest one. A tangent representing the price of corn to protein supplement may be constructed at any point on the iso-production curve.

A third and more concise method of computing the minimum feed cost combination is by equating the derivative of y (corn) with respect to X (high protein) to the inverse price ratio preceded by a minus sign. Thus $\frac{dy}{dx} = \frac{-P_x}{P_y}$ This is the mathematical approach to the method presented above. For the iso-product curve of 125-200 pound hogs (other weight hogs as 78-125 pounds may have a different iso-product curve) used in this paper and presented in fig. 1, the formula would be $\frac{-7418.5}{x^2} = \frac{-P_x}{P_y}$. The value of x is found by inserting the price ratios. For example, if P_x equals $3.00 per hundred pounds and P_y equals $1.00 per hundred pounds then $\frac{-7418.5}{x^2} = \frac{-3}{1}$; $x = 49.7$

Substituting this value of x into the original equations gives 228 pounds as the y component. This is the least cost combination of producing 100 pounds of pork with the price ratio 3 to 1 for this particular iso-product curve. The graph in figure 1 shows that this is point G. If a line with a price ratio of 3 to 1 were constructed, it would be tangent to the iso-product curve at this point.

CONCLUSIONS

Research results may appear insignificant to small individual producers, yet these results become an imposing total when considered as the sum of all producers in agricultural economy. For example, this paper shows that the feed cost per hundred pounds of pork produced with a price ratio of corn to high protein feed of 1.5 to 2.5 would be approximately 60 cents more for a 12 per cent protein ration than a ration containing 17 per cent protein. To an individual with 200 head of hogs, this would mean nearly $100 in feeding the hogs from 125 pounds to a marketing weight of 200 pounds. If the assumption were made that all the producers in the nation were feeding a 12 per cent protein ration with a price ratio of 1.5 to 2.5, the savings to the economy for one year would be about 27 million dollars. Actually part of this loss would be absorbed

by the consumer. If all resources of production were employed at minimum feed costs, the total output would be greater resulting in a lower price per unit of the product. In other words, the consumer could buy meat at a lower price per pound.

Additional research is needed, from an economic standpoint, to determine the substitution rates of various feeds that will replace each other in rations for different weight hogs. Heady *et. al.*, recently have done considerable work in this phase, but much additional work is greatly needed.

SUMMARY

The price of corn and high protein feeds varies from year to year. These changing prices often create situations where it is more profitable for a hog producer to use a high protein content ration one year and a lower protein ration another year.

Marginal rates of substitution of high protein feed for corn is defined as the ratio of the amount of corn that is replaced by the addition of the last unit of high protein feed. For example, if 1 pound of high protein feed were added to a certain ration 3 pounds of corn could be taken out and both rations would produce the same amount of pork. The marginal rate of substitution would be 3 to 1. The least feed cost combination is found by equating the ratio of the prices of corn and high protein feed to the marginal rate of substitution. Since the marginal rate of substitution varies at different levels of corn and high protein feed combinations and the prices of the feeds change, the least feed cost ration of corn and high protein feed changes.

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An Introduction To The Genus Rosa With Special Reference To R. Acicularis[1]

WALTER H. LEWIS[2]
The Blandy Experimental Farm
University of Virginia

Although the second half of this paper alone was awarded the J. Shelton Horsley Research Prize, it is felt that an introduction to genus *Rosa*, especially in eastern North America, would logically begin a series of papers on the problems of *Rosa* speciation from this continent. One of the most interesting taxa is *R. acicularis* Lindl. — the complete text of which is being published elsewhere.

I. THE GENUS *ROSA*

(*Rosa* (Tourn.) L. Sp. Pl. 491, 1753

The species of the genus are characterized as: woody perennials, upright or trailing, usually with prickly stems; leaves alternate, compound or rarely simple, typically with adnate stipules or rarely absent, leaflets 3-15, serrate or biserrate, often pubescent and glandular; flowers perfect, solitary, corymbose or paniculate, sepals 5, rarely 4, petals 5, rarely 4, or by transformation of the stamens numerous, obovate or or obcordate, stamens numerous inserted on a disk at the margin of the hypanthium, ovaries numerous within the hypanthium, styles connate or free, included or exserted, stigmas thickened; hypanthium urceolate or globose, contracted at the mouth, becoming fleshy at maturity (the hip); fruit an achene.

The type species for the genus is *Rosa cinnamomeae* L. Sp. Pl. 1: 703 (1764), *habitat in Europa australi.*

The genus *Rosa* is distributed throughout the northern hemisphere below the tree line to a southern limit in North Africa, Ethiopia, southern India, Burma, the Phillipine Islands, Mexico, and central Florida. In North America the genus is a predominant part of the flora of central and southern Canada, and northern United States. It is by no means uncommon in other regions of the continent, for at least two species are native to each state in the United States, to each Canadian province

[1] For his guidance and encouragement during the course of this study, the author is indebted to Dr. W. S. Flory, Jr.

[2] Present address: Department of Biology, Stephen F. Austin State College, Nacogdoches, Texas.

and territory, to Alaska, and to northern Mexico.

Although many schemes of intrageneric classification have been suggested since the first proposal by De Candolle (1818), the one sketched by Crepin (1887) is the form most widely used. He divided the genus into fifteen sections including: I, Synstylae DC; II, Stylosae Crep.; III, Indicae Thory; IV, Banksianae Lindl. (Bankseae Crep.); V, Gallicanae DC (Gallicae Crep.); VI, Caninae Crep.; VII, Carolinae Crep.; VIII, Cinnamomeae Crep.; IX, Pimpinellifoliae DC; X, Luteae Crep.; XI, Sericeae Crep.; XII, Minutifoliae Crep.; XIII, Bracteatae Thory; XIV, Laevigatae Thory; and XV, Microphylae Crep. With several modifications, Crepin's sectional division of the genus is adopted.

Focke (1888) separated the roses of the world into two subgenera, *Hulthemia* Du Mortier (1824) with one species, *R. persica* Michx. distinguished from the other species by simple leaves lacking stipules. All remaining species have compound leaves with stipules and are grouped into the subgenus *Eurosa* Focke. Some authors (Hurst 1928) have considered *R. persica* quite distinct from the genus *Rosa* and they believe that the species should be represented by the genus *Hulthemia*. Other monotypic generic names have been introduced to characterize *R. persica*, as for example, *Lowea* (Lindley 1829) and *Rhodopsis* (Ledebour 1830). It is generally agreed, however, that this species is the most primitive member of the genus *Rosa* (Harrison and Blackburn 1927) having not yet developed compound leaves or stipules. This separation of *Rosa* into two subgeneric taxa has been followed in the present study, thereby reducing the genera *Lowea* and *Rhodopsis* to synonymy under the subgenus *Hulthemia* (Du Mortier) Focke.

Within the subgenus *Eurosa* Focke, several species have been distinguished by new genera: *R. microphylla* Roxb. as *Platyrhodon microphylla* by Decaisne (1850); *R. bracteata* Wendl. as *Ernstella bracteata* by Germain de St. Pierre (1878); and the species of the section Minutifoliae (*R. minutifolia* Engel., *R. stellata* Woot., and *R. mirifica* Greene) as subgenus or genus *Hesperhodos* by Cockerell (1913). Although these species have several unique characters such as numerous, up to 15, leaflets in *R. microphylla*, tomentose inflorescence and hips in *R. bracteata*, and few, small, incised leaflets in *R. minutifolia*, *R. stellata*, and *R. mirifica*, they are not considered sufficiently important for exclusion from the genus *Rosa* or to represent even a major rank above section.

Necker (1791) neglected the generic name entirely and created the synonym *Rhodophora*.

In North America, the native species were grouped by Crepin (1887) into four sections: Cinnamomeae, Carolinae, Synstylae, and Minutifoliae. The latter two sections are readily separable from all others. The styles

of the Synstylae species are united forming a column projecting well above the disk of the hypanthium, while the very small, incised leaflets distinguish the species in the section Minutifoliae. The section Carolinae was separated from the section Cinnamomeae on the basis of the ovary position within the hypanthium and by the position of the sepals on the hypanthium at maturity and by their degree of persistence. A further character, glandular-hispid hypanthia, has been used by Rydberg (1918), Rehder (1927), Fernald (1950) and others, to differentiate these sections. The section Carolinae has been characterized by ovaries that are inserted exclusively at the base of the glandular-hispid hypanthium with spreading or erect caducous sepals. On the other hand, the species of the section Cinnamomea have ovaries lining the walls as well as the bases of the smooth hypanthia, with erect and persistent sepals.

Boulenger (1925) found that the mode of carpel insertion in the hypanthium is an inconsistent character in *Rosa*. Further, Erlanson (1934) stated that the achenes of *R. palustris* Marsh. (section Carolinae) are frequently attached to the side wall of the hypanthium while *R. blanda* Ait., *R. Woodsii* Lindl., *R. pisocarpa* Gray and other species of the section Cinnamomeae can be found with achenes at the base of the hypanthium only. The sections Carolinae and Cinnamomeae can hardly be separated on the basis of ovarial position when no degree of discontinuity exists.

Sepals may be erect, spreading, or reflexed on the mature hypanthia in different individuals of the same culture in *R. Woodsii* Lindl., *R. pisocarpa* Gray, and *R. californica* C. & S. (*Cinnamomae*), and *Woodsii* and *R. pisocarpa* have been observed with deciduous sepals Erlanson (1934). It is interesting that Crepin (1887) included *R. gymnocarpa* Nutt. as a Cinnamomeae species, yet this taxon is the most consistent example of a species with caducous sepals in North America even to the extent of establishing a new section (Gymnocarpae) on this and other characters by Rydberg (1918). Erlanson (1934) noted the occurrence of persistent sepals for *R. palustris* Marsh. (Carolinae). Since Crepin used persistent and erect sepals to characterize the section Cinnamomeae and spreading or erect and caducous sepals to typify the section Carolinae, there is little value in using the sepal characteristics for this purpose in view of the major discrepancies cited above.

Although all species of the section Carolinae have typically glandular-hispid hypanthia, a few individuals of *R. virginiana* Mill., *R. foliolosa* Nutt., *R. nitida* Willd., and *R. carolina* L. have been observed with smooth hypanthia. Several well known glandular-hypanthia Cinnamomeae forms including *R. nutkana* Presl var. *hispida* Fern., *R. blanda* Ait. var. *hispida* Farw. and a new form of *R. Woodsii* Lindl. illustrate that the section Carolinae is not unique from the section Cinnamomeae in having

individuals with glandular-hispid hypanthia. Smooth and hispid hypanthia, therefore, occur in the species populations of both sections.

Since the characters used by Crepin and others to distinguish between these sections have little consistency, the sections are re-grouped under the older name, Cinnamomeae. The species of the three sections found in North America east of the Rocky Mountains are grouped as follows:

Subgenus *Eurosa* Focke

Section Cinnamomeae DC
(section Carolinae Crep.)
(section Gymnocarpae Rydb.)

1. *R. carolina* L. Sp. Pl. 1: 492 (1753) (non L. 1762).
2. *R. virginiana* Mill. Gard. Dict. ed. 8, no. 10. (1768).
3. *R. palustris* Marsh. Arb. Am. 135 (1785) .
4. *R. blanda* Ait. Hort. Kew. 2: 202 (1789).
5. *R. nitida* Willd. Enum. Pl. Berol. 544 (1809).
6. *R. acicularis* Lindl. Ros. Mon. 44 (1820).
7. *R. Woodsii* Lindl. Ros. Mon. 21 (1820).
8. *R. foliolosa* Nutt. ex Torr. & Gray Fl. N. Am. 1: 460 (1840).
9. *R. arkansana* Porter ex Porter & Coulter Syn. Fl. Colo., U. S. Geol. & Geog. Surv. Misc. Pub. No. 4: 28 (1874).

Section Synstylae DC
(section Synstylae Lindl.)

1. *R. setigera* Michx. Fl. Bor.-Am. 1: 295 (1803).

Section Minutifoliae Crep.
(genus or subgenus *Hesperhodos Ckll.*)

1. *R. stellata* Woot. Bull. Tor Bot. Cl. 25: 152 (1898).
2. *R. mirifica* Greene Leafl. Bot. Obs. 2: 62 (1910).

II. SUMMARY OF A BIOSYSTEMATIC STUDY OF *R. ACICULARIS*.

The native roses are one of several groups of plants notoriously difficult to separate into distinct species with definite, definable limits. The ease with which species hybridize giving fertile offspring and the wide, often overlapping, range of morphological variation within each species are factors contributing to this problem of speciation. As a result of isolation and of wide geographical ranges, rose species have

in some instances evolved infraspecific complexities separable not only on gross morphological evidence, but cytological and phytogeographical as well.

Such an example is *R. acicularis* Lindl., a bristly stemmed species native to northern Europe, Asia, and North America from Alaska to New Mexico, across Canada and northern United States to New Brunswick and West Virginia, respectively. This is by far the widest natural range of any species in the genus.

In North America the species has often been confused with *R. blanda* Ait., *R. Woodsii* Lindl., and *R. arkansana* Porter, all of which by one or more characters resemble *R. acicularis*. In addition, individuals of the taxon can hybridize with *R. nutkana* Presl and intermediate forms between the two are common west of the Rocky Mountains from Alaska (Hulten 1946) to Colorado.

Within the species there has never been a comprehensive study of material from both Eurasia and North America. Due to the generosity of the curators of several herbaria in Sweden and the U. S. S. R., such a study has been possible and it has been found that the Eurasian population varies from the North American population by at least nine morphological characters. Not only is there an observable variation, but the number of chromosomes differ – the population in Eurasia has 56 chromosomes (octoploid) while only 42 chromosomes (hexaploid) in North America.

In eastern Siberia and Alaska typical Eurasian and North American individuals are found together with a greater percentage of morphologically appearing intermediate forms. Since the members of the two populations differ in chromosome number, cytological evidence from these 'intermediate' forms would be critical in determining if the apparent hybridizations are an actuality. Although no septaploid plant has yet been observed, an individual from a controlled cross has been found to have 49 chromosomes.

The characteristics of the two populations of *R. acicularis* can be summarized as follows (morphological data based on 200 specimens):

(1) in Eurasia – leaves 5-foliolate (91%), leaflets eglandular below (78%) with singly serrated (86%), eglandular (82%) serrations and with fewer than eighteen serrations per half leaflet (88%), petioles without bristles (83%), one auricle 5mm. or more wide (62%), pedicels glandular (89%), sepals less than 3 mm. wide at their bases (59%); chromosome number of 2n = 56; native to Eurasia and Alaska.

(2) in North America – leaves 7-foliolate (53%), leaflets glandular below (85%) with partly or entirely biserrated margins (69%), the

serrations gland-tipped (67%) and with eighteen or more per half leaflet (57%), petioles bristly (43%), one auricle less than 5 mm. wide (58%), pedicels eglandular (92%), sepals 3 mm. or more wide at their bases (78%); chromosome number of 2n = 42; native to North America and eastern Siberia.

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Headward Growth Of Anticlinal Valleys In The Karst Cycle Of Erosion

CHARLES F. LANE
Longwood College, Farmville, Virginia

Numerous articles have been written (see literature cited) about erosion and erosion cycles in horizontal limestone formations and in folded strata of unequal resistance. The literature dealing with structural folds has been concerned mostly with the development of stream patterns and the evolution of relief features in the fluvial cycle of erosion. The important karst processes that have been active in the headward growth of anticlinal valleys have been neglected.

While working on a physiographic field problem in the Cumberland Plateau of Tennessee, the writer noted numerous surface features that had resulted from water solution and subterranean streams in the head of Sequatchie Valley. This valley has been eroded along the axis of an anticline that extends for nearly 200 miles from Cumberland County, Tennessee, southwestward into Alabama. A study of Grassy Cove and vicinity (Fig. 1), located to the northeast and in line with the longitudinal axis of Sequatchie Valley, reveals the dominant role that karst processes are playing in its headward erosion and growth.[1]

The sequential stages in the fluvial and karst cycles of erosion that led to the landforms in Grassy Cove and its vicinity will be presented in this paper. The author believes that a study of the coves and valleys in this area helps to explain the erosional processes and stages during the geomorphic evolution of Sequatchie Valley and other valleys in the folded Appalachians.

STRATIGRAPHY AND STRUCTURE

The rock formations in the area of this study are shales and indurated sandstones of Pennsylvania age and shales and limestones of Mississippian age. The floor of Sequatchie Valley is underlain predominantly by Cambrian and Ordovician limestones. The formations in the Grassy Cove area are as follows: Fort Payne chert, Warsaw limestone, St. Louis limestone, Ste. Genevieve limestone, Gasper odite, Hartselle sandstone, Bangor

[1] The Sequatchie Valley fault along the western side of Sequatchie Valley should be mentioned in relation to the straightness of this valley. However, the center of Sequatchie Valley follows closely the axis of the anticline rather than the fault. Furthermore, the fault does not extend into Grassy Cove which is along the axis of the anticline. This indicates the fault is not the controlling factor in the headward growth of Sequatchie Valley. The disturbances along the western side of Sequatchie Valley are reflected in the steep monoclinal dip 1,000 feet northwest of Grassy Cove.

limestone, Pennington shale, all of Mississippian age; Gizzard formation, Sewanee conglomerate, Whitwell shale, Herbert sandstone, Eastland shale, Newton sandstone, Vandever shale, Rockcastle sandstone, Duskin Creek formation, all of Pennsylvanian age.

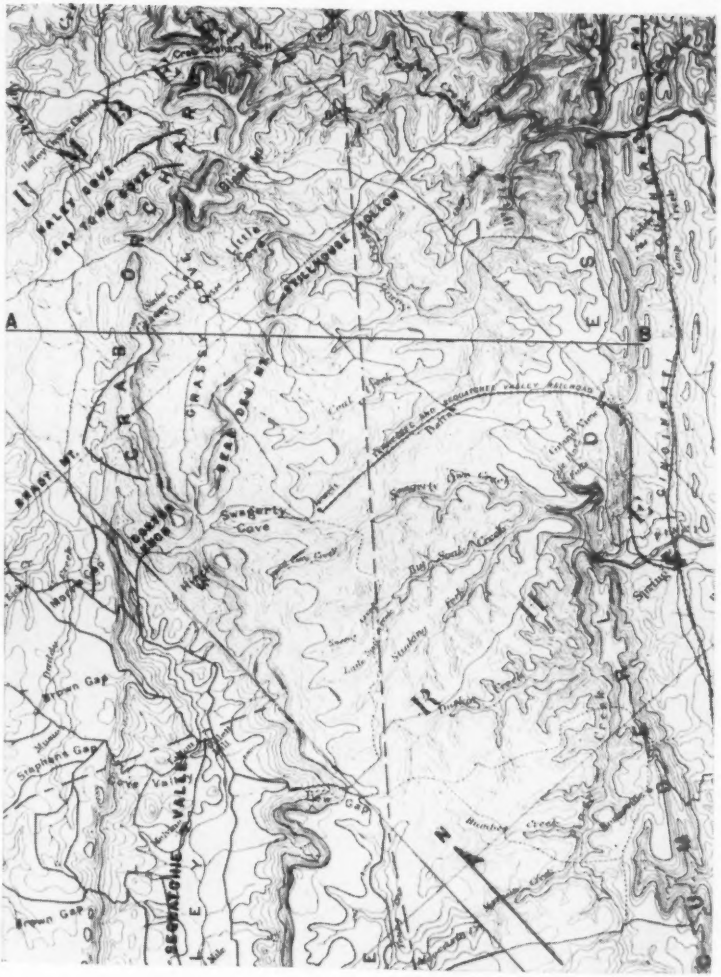
Pennsylvanian formations cap most of the Cumberland Plateau in Tennessee. Generally, the strata have low dips that comprise broad shallow synclines and broad anticlines. Along the Cumberland Escarpment the beds dip steeply to the northwest but flatten out quickly a few hundred feet to the west (Fig. 2). Eight and one-half miles northwest of the Cumberland Escarpment, and parallel to it, the strata have been bent into a singular fold called the Sequatchie anticline. The formations along the axis of this fold stand generally between 1,000 to 1,500 feet higher than the corresponding ones on the surrounding plateau.

The steep head of Sequatchie Valley terminates against precipitous escarpments of the Crab Orchard Mountain, locally called Dorton Knob and Brady and Hinch mountains. The crests of these mountains stand 1,900 feet above the valley floor. This difference in elevation occurs within a distance of one mile. Although Sequatchie Valley ends against these mountains, the processes that were so active in its formation are continuing their work to the northeast along the anticline. Six coves have been eroded into the crest and limbs of this fold, and each one represents a different stage in the fluvial and karst cycles of erosion. Grassy Cove is the largest with an area of 5.1 square miles. The northeast-southwest segment of this cove is located along the crest of the Sequatchie anticline, whereas the north-south segment is on the northwestern limb. Smaller coves are also located on the northwestern and southeastern flanks of the fold.

THE FLUVIAL CYCLE OF EROSION

The forces that caused the folding of the rock formations in the Ridge and Valley Province also affected the strata of the Appalachian Plateaus. In general, only minor folds were formed in the Cumberland Plateau of Tennessee, however, a major one was the Sequatchie anticline.

During uplift and folding, surface streams were adjusting to the regional topography. Major longitudinal consequent streams followed the broad synclinal troughs, such as White and Piney creeks southeast of the Sequatchie anticline and Daddy Creek to the northwest (Fig. 1). These were joined by secondary lateral consequents which descended the limbs of the anticline. Today, the heads of the lateral consequent valleys extend almost to the cuesta escarpments overlooking the coves. A few of these lateral streams were able to cut through the resistant Sewanee conglomerate which caps the crest and the higher parts of the Sequatchie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Cove Creek
Mill Creek
Little Creek
Rattlesnake Hollow
Valley Gap
Gap Cove
Gap Creek
Cross Mountain
Mountain Creek
Mountain Gap
Mountain Gap Creek
Deep Gap
Deep Gap Creek
Deep Gap Trail
Cumberland Valley
Cumberland Front
Cumberland Plateau
Cumberland Mountains
Cumberland Gap
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Cumberland Mountain Tunnel
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anticline. A typical example is in the upper valley of Coal Creek where this stream has eroded through the Sewanee and exposed the weaker shales of the Gizzard formation. After the cap rock was breached, the streams were able to extend their valleys rapidly by sapping and headward erosion. After the valley-heads had reached the crest of the anticline, further erosion was along its axis. This is exemplified on the eastern side of Grassy Cove by Stillhouse Hollow, a deep wind gap made by an eastward-flowing lateral consequent stream. After this stream worked its way into the crest of the fold, any further erosion had to be toward the highest summit along its axis. In Grassy Cove the Sequatchie anticline plunges to the northeast, hence the headward erosion was to the southwest. The erosion along the axis was governed by structure and gave rise to the subsequent valley which forms the southwestern arm of the cove.

It is generally accepted that headward erosion by subsequent streams along the crest of an anticline continues until the fold is breached and a large anticlinal valley is formed. This was the sequence in the southwestern section of Grassy Cove until the normal fluvial cycle of erosion was interrupted and the karst cycle was initiated by subterranean drainage. Not only was the cycle interrupted along the axis of the fold but also on the flanks where the lateral consequent streams had cut through the resistant cap rock of the Sewanee conglomerate. Since these streams cut through the Sewanee formation high on the limbs of the fold, they must flow across this formation again downstream. This resistant rock extending across the lower end of the incipient gashes serves as a local base level. Upstream from the base level, downward cutting continues for a time, but as the bed of the stream nears the local base level lateral cutting becomes important. The original valleys are lowered and widened until the Gizzard and Pennington formations are removed and the soluble limestones of Upper Mississippian age are exposed.

KARST CYCLE OF EROSION

The exposure of the Mississippian limestones marked a new phase in the cycle of erosion and in the headward growth of Sequatchie Valley. Incipient sinks and dolines began to form along fissures in the Bangor limestone. The surface streams were eventually diverted underground by the sinks and dolines. This diversion was geologically recent because the

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Cumberland Plateau called Walden Ridge, and the straight alignment of Grassy Cove and Sequatchie Valley. Longitudinal consequent streams, such as Daddy, White, and Piney creeks, and lateral consequent streams, such as Fall, Sandy, Coal, Swagerty, Big Soak, and Duskin creeks, can be seen.

Fig. 2. A generalized cross-section of Walden Ridge and Grassy Cove. Shows the structure and rock systems between A and B on figure 1. O=Ordovican, S=Silurian, M=Mississippian, and P=Pennsylvanian.

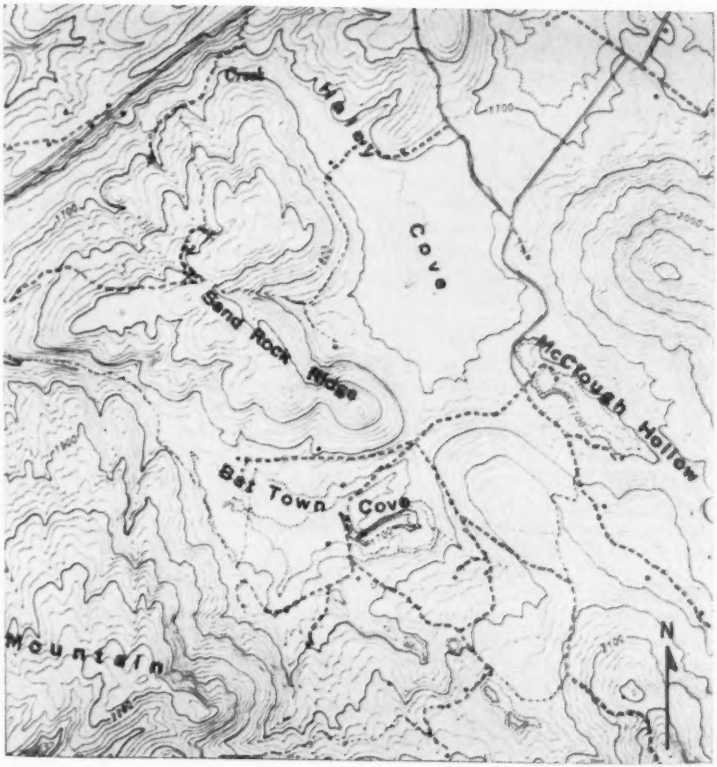

Fig. 3. Two minor coves on the northwestern limb of the Sequatchie anticline. Part of the Dorton quadrangle map of the Tennessee Valley Authority Survey. Horizontal scale 1/24,000, contour interval 20 feet. McClough Hollow is an incipient sink developing in the Gasper limestone and rimmed by the impermeable Hartselle sandstone. This sink has captured the headwaters of Haley Creek, but most of Haley Cove is

deep wind gaps which extend through the mountains surrounding the coves are only 40 to 100 feet above the cove floors. Haley Cove is the only one today drained by a surface stream.

The dolines and sinks were enlarged by solution and sapping, and some coalesced by collapse of cavern roofs. As a result of these processes many of the resistant rock units stand as prominent bluffs along the mountain sides overlooking the coves. Many rock falls and landslides from the undercut bluffs are evident by the great mass of debris around the margins of the coves.

While the sides of the coves were retreading by the processes of solution and sapping, the cove floors were being lowered by solution and underground erosion. The subterranean streams enlarged the fissures and caverns until their downward erosion was halted by the impermeable Hartselle sandstone in Haley and Bat Town coves and sandy phases of the Warsaw limestone in Grassy Cove. Both of these formations are composed, in part, of very hard, dense, and calcareous sandstones. They, therefore, completely stop or interrupt the sequential steps in the karst cycle of erosion.

While this cycle of erosion was interrupted by the impermeable strata, water was slowly penetrating their joints and fissures. Subsequently, another limestone formation was encountered by the descending water and a new cycle of karst erosion was initiated. This is well illustrated in Haley and Bat Town coves where large sinks have appeared in the Hartselle sandstone, exposing the underlying Gasper limestone (Fig. 3). The surface stream in Bat Town Cove has already been diverted underground through one of these sinks. However, the sink in Haley Cove has not yet captured all of the surface drainage.

From this study, it is evident that the surface features in this area have been developed by two types of erosion cycles. The initial stages in the evolution of the topography resulted from the normal fluvial cycle of erosion on folded strata, whereas the later stages resulted from the karst cycle of erosion. The lateral and downward erosion and enlargement of the sinks and valley coves involve numerous agents and processes. The divides separating the coves and Sequatchie Valley will slowly be removed by sapping and collapse of the resistant strata, by headward erosion of a few surface streams, and by subsurface erosion and solution. The latter process not only forms a large network of caverns, but also

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drained by a surface stream to the northwest. Bat Town Cove shows sub-surface drainage into a sinkhole on the eastern side of the cove. Drainage was formerly through the wind gap to the west of the cove.

causes collapse or slump of some areas into the caverns which lie from 200 to 400 feet below the surface as illustrated by large sinks in sandstone and shale on the mountain crest surrounding Grassy Cove.

SUMMARY

The topography in the area to the northeast of Sequatchie Valley and in line with it has evolved on an anticline. The initial erosion was by surface streams, whereas the more recent erosion and enlargement has been by solution and subterranean streams. The various stages in the karst cycle of erosion are illustrated in the separate coves as well as the processes that were active during different stages of development. By studying the various phases of erosion in the several coves, the steps in the future headward growth of Sequatchie Valley can be determined. It may be assumed that the same processes that are so active at the present time were also active in forming the entire Sequatchie Valley and many of the valleys in the Ridge and Valley Province.

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News and Notes

(Editor's Note: News contributions should be sent to the person whose name appears at the end of the appropriate sections.)

FOLEY FOSTER SMITH — AN APPRECIATION

When the late Dr. E. C. L. Miller, of revered memory, resigned as secretary-treasurer in 1949, The Virginia Academy of Science was faced with one of its major decisions. Who would take his place? After all, Dr. Miller was one of the founders of the Academy in 1923 and served as secretary-treasurer since that date — a tenure of 26 years. Fortunately for science in Virginia, Dr. Miller's last official recommendation was that the office be turned over to the assistant secretary-treasurer, Foley Smith, and Dr. Miller's recommendation was unanimously approved by the council.

Were Dr. Miller alive today, he would be pleased with the work that Foley Smith has done. Foley has been a good secretary-treasurer and with him in this office the academy has continued to prosper. The continuing growth of the activities of the academy has matched the expansion of science in the Old Dominion and has made it imperative to afford some relief to the secretary-treasurer. Accordingly, the council at its meeting on May 11, 1957, voted to divide the office into two — a secretary and a treasurer. Again, fortune favors the academy because Foley agreed to remain as secretary, in which position he will continue to give his wise counsel and unflagging loyalty to serve the Academy.

— George W. Jeffers, *Longwood College*

AGRICULTURAL SCIENCE SECTION

Dr. D. G. Cochran joined the staff as Associate Entomologist on May 1. He will do research on insect physiology. He received his B.S. from Iowa State, his M.S. from Virginia Polytechnic Institute and his PhD. from Rutgers.

Dr. J. W. Gossett arrived at Virginia Polytechnic Institute on June 10. He will teach and do research in the field of Physiology of Reproduction.

— Carl W. Allen, *Virginia Polytechnic Institute*

ASTRONOMY, MATHEMATICS, PHYSICS SECTION

Professor Frank S. Hereford of the Physics Department, University of Virginia, has received a Fulbright Scholarship for the coming academic year. He will work with the high energy synchro-cyclotron at the University of Birmingham, England.

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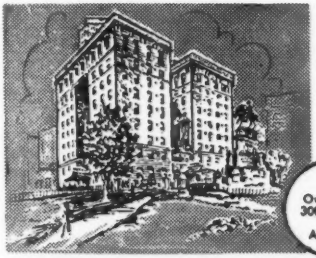

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Dr. A. N. Vyssotsky of the McCormick Observatory has been invited to take part in a "Symposium on the Coordination of Galactic Research." The symposium met in Stockholm in June, 1957.

Dr. Paul McCorkle, recently retired Head of the Department of Physics at Bradley University, has been a Visiting Professor at William and Mary this year. Dr. McCorkle will go to Roanoke College next September as Head of the Physics Department.

Virginia Polytechnic Institute has been chosen as one of the colleges which will offer special AEC Fellowships in Nuclear Energy Technology.

Additions to the staff of Virginia Polytechnic Institute for the coming year are Dr. C. D. Bond, recently at the University of Vigrinia, and Dr. W. B. Payne who is presently a member of the staff at Johns Hopkins.

Professor J. W. Beams, Chairman of the Department of Physics at the University of Virginia has recently been elected Vice-President of the American Physical Society.

The University of Richmond has announced that a graduate program in Physics will begin in September 1957. The degree of Master of Science will be offered. Fields of interest are solid state physics, nuclear physics, and radiation detection. Teaching assistantships are available, and the program will stress close faculty-student relationships. Inquiries may be made of Professor J. J. Taylor, Chairman, Department of Physics.

Frederick R. Crownfield, Jr., has joined the faculty at William and Mary as Assistant Professor of Physics. Dr. Crownfield was formerly at North Carolina State.

— Irving G. Foster, *Virginia Military Institute*

BIOLOGY SECTION

Mr. Aaron H. O'Bier has accepted the position at Longwood College as Research Assistant under a contract with the Atomic Energy Commission. Mr. O'Bier holds a masters degree from the University of Richmond and has done graduate work at the Virginia Polytechnic Institute.

— Robert T. Brumfield, *Longwood College*

CHEMISTRY SECTION

A $1000 Grant for Instrumentation, for the purchase of a refractometer and hydrogenator has been received jointly by Dr. Grossnickle and Dr. Heisey, from the National Science Foundation in June, 1957.

— M. A. Kise, *Virginia Smelting Company*

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GEOLOGY SECTION

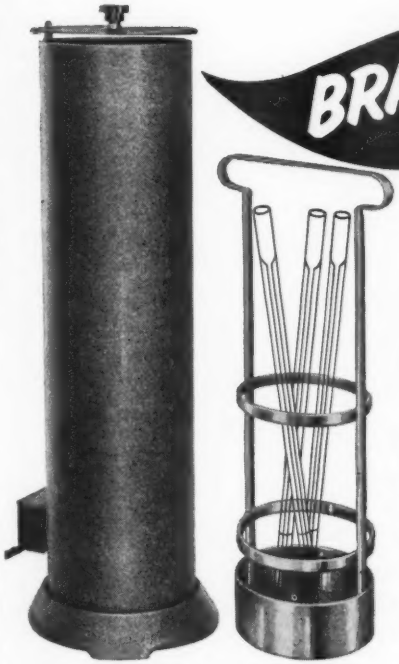
Dr. James L. Calver has recently been appointed Commissioner of the newly reorganized Division of Mineral Resources in Virginia's Department of Conservation and Development. Dr. Calver will also serve as State Geologist of Virginia. Before his appointment, Dr. Calver was geologist for the Florida Geological Survey and prior to joining that organization was engaged in several different types of geological activity. He obtained his doctor's degree from the University of Michigan and has served on the faculties of the University of Missouri and the University of Wichita.

Bruce Hobbs, Jr. has recently joined the Division of Mineral Resources as a geologist. Hobbs' doctorate was written on the "Petrography and Origin of Ordovician Dolomite-bearing Carbonate Rocks of Western Virginia," and was published in the March (1957) bulletin of the Virginia Polytechnic Institute, Virginia Engineering Experiment Station series.

The Division of Mineral Resources has begun a program of summer field work which includes the following projects: The completion of detail mapping, study, and collection of samples of clays and shales from the Danville Triassic Basin. This work is to be done by Carl T. Meyertons. This is a cooperative project with the Virginia Engineering Experiment Station. Harvey C. Sunderman will study the geological and mineral resources of the Piedmont region. He will be assisted by John Tappe.

The American Petroleum Institute has renewed its grant-in-aid to Bruce W. Nelson who is conducting a sedimentation study in the Rappahannock River. The object of this study is to discriminate between transportation and diagenetic factors as contributors to the clay mineral composition of sediments. Source sediments, bottom estuarine muds, and suspended sediments in the river and estuary are being studied mineralogically and chemically. Field work will be done in June and August, 1957.

Dr. Edgar W. Spencer has been appointed Assistant Professor of Geology at Washington and Lee University to succeed Dr. Troy J. Laswell who resigned to go to Louisiana Polytechnic Institute. Dr. Spencer received his A. B. degree *cum laude* from Washington and Lee in 1953 and his PhD. in structural geology from Columbia University in June, 1957. Since receiving his bachelor's degree he has done summer work with the Atomic Energy Commission in Montana, the Lamont Geological Observatory under Dr. Maurice Ewing on oceanographic studies between New York and Africa, and has made studies of the mechanics of deformation in the Pre-Cambrian crystalline core of the Beartooth



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"Is Anthraxolite Related Genetically to Coal or to Oil?" is the subject of a paper by R. V. Dietrich which appeared in *Economic Geology*, vol. 51, no. 7, November, 1956. Anthraxolite from Montgomery County, Virginia, is among those discussed in the paper. Dietrich also described "Trigonal Paragonite from Campbell and Franklin Counties, Virginia" in the *American Mineralogist*, vol 41, 1956.

"Implications of Gentle Ordovician Folding in Western Virginia" are discussed in an article by W. D. Lowry in the April issue of the AAPG *Bulletin*.

Ralph L. Miller has been appointed chairman of the AAPG Committee on Preservation of Samples and Cores. W. D. Lowry will serve on the committee as the member in charge of most of the Atlantic Coast states. R. V. Dietrich is serving on the AAPG "Basement Rocks Project Committee." He is collecting data on the buried basement in 18 different eastern states.

Byron N. Cooper discussed synchrony of Appalachian sedimentation and tectonism on his recent AAPG distinguished lecture tour of many U. S. and several Canadian cities.

At the G.S.A. Southeastern Section meeting at Morgantown, West Virginia, May 16, and 17, much Virginia geology was discussed. Frank Lesure spoke on "Iron Deposits of the Clifton Forge Area, Virginia;" Harvey Sunderman on the "Geology of the Scottsville Basin, Virginia;" R. V. Dietrich on the "Origin of the Blue Ridge Escarpment Directly Southwest of Roanoke, Virginia;" C. E. Sears on "Late Cretaceous Erosion Surface in Southwest Virginia;" and W. D. Lowry on the "Betts Quarry Case, Harrisonburg, Virginia." One afternoon session was devoted exclusively to a symposium on "New Geophysical Data and Their Relation to Surface Geology of the Central Appalachians." John C. Maxwell served as moderator. The symposium began with a formal paper by Robert W. Johnson, Jr. on "Regional Geophysical Data and Their Relation to the Appalachians in Central and Western Virginia." A second formal paper on "Gravity-anomaly Patterns in Virginia" was presented by G. P. Woolard. These papers were followed in turn by rather informal discussions of the geology of the Piedmont, Blue Ridge, Valley and Ridge, and Plateau provinces of Virginia by W. R. Brown, R. O. Bloomer, Byron N. Cooper, and Rhesa M. Allen, Jr., respectively.

The science exhibits of the Virginia Junior Academy of Science at Old Point Comfort featured several of geological nature. In the Miscellaneous Division, first prize of $50.00 was won by Vernon Rollins of Hampton High School for his "Geological Survey of New Market Creek" and second

prize of $30.00 was won by Randolph Bland, Jr. of Thomas Jefferson High School, Richmond, for his collection of "Virginia Rocks and Minerals." In the Biology Division, Honorable Mention was won by Godfrey Smith for his display of the "Paleontology of the Lower York-James Peninsula."

— W. D. Lowry, *Virginia Polytechnic Institute*

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